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Wireless Nurse Call System in Medical Institutions

Mohamed Hesham Aref[1,*], Ahmad Aly El-Shinnawi[2], Amr A. Sharawi[3]

[1]Biomedical Engineer in the Military Forces, Cairo, Egypt
[2]Senior Research Engineer, Cairo, Egypt
[3]Biomedical Engineer Department, Cairo University, Cairo, Egypt
*Corresponding author: heshame120@hotmail.com

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Abstract Nurse Call systems are very important for any medical center / ICU center / hospital, thus affecting indirectly the patient's life. The basic idea of this paper is to design and implement a complete wireless nurse call system in the hospital, displaying the patient room number on a desktop computer LCD. Our proposed system implements a smart controller and several wireless switches using RF technology to continuously monitor and display the state of any room / patient / medical help or assistance needed, in order to provide fast and respectable medical service without any human errors or medical assistance delay, which could occur at any instant of time during system preparation or installation. Our system has succeeded in monitoring up to 5 rooms at the same time collecting real-time data as a prototype. It can be extended to up to 254 monitoring points.

Keywords: *wireless nurse call system, medical assistant, wireless medical call, MESH network, Arduino Nano board, Arduino mega, Raspberry Pi 2 model B, Raspberry Pi 3, UART RF Board*

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1. Introduction

A wireless nurse call system is a new advancement technology which holds the latest cutting edge wireless methods at its core. This enables patients to use them in such an easy and comfortable way, receiving its medical assistance quickly. Since it does not need the usage of any wires like old versions of nurse call systems, it becomes very simple for hospital staff to deploy and use it within minutes. Wireless nurse call systems are scalable from a few beds to so many. No future maintenance is needed, as the medical assistant could affect directly the patient health in the hospital. This has become so important, ever since quality and reliability have deemed so critical in patient and life safety according to the regulations imposed by the Federal Food, Drug, and Cosmetic Act (FDA), as well as other medical standard codes such as the European Standard (**ISO 7369**) and the American Standard (**NFPA 99**) [1,2,3].

The main configuration of our proposed system has been applied to five hospital patient rooms as shown typically in Figure 1 [4]. It particularly features the following:

1) Arduino Nano board which could be battery operated
2) Wireless Transceiver serial UART (for the RF operation) located in each patient room
3) Push button switches
4) Raspberry Pi2 Model B for the monitoring station
5) LCD computer screen for the final data display [4].

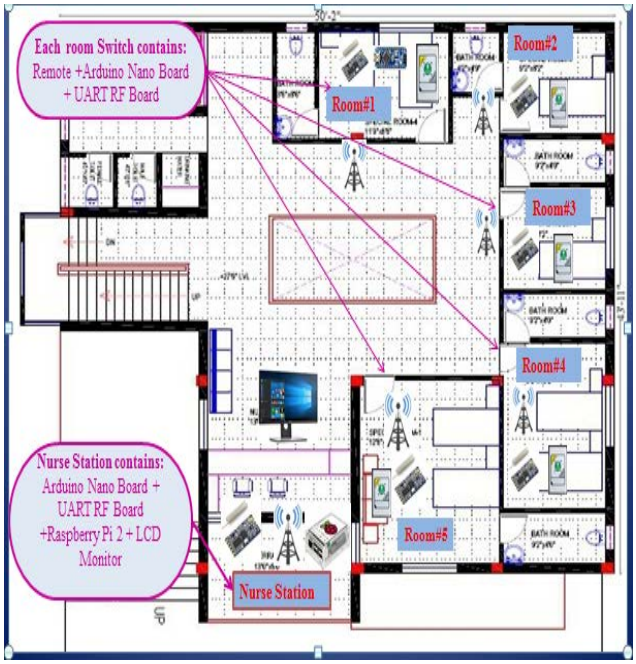

Figure 1. Wireless Nurse Call system configuration

1.1. Review of Previous Work

1. Most investigators have designed a simple device by using wires, buzzers and LEDs, besides the old technology of switches and/or seven segments displays as shown in Figure 2 [5,6].

Figure 2. Basic Wired Nurse Call System

2. Previous devices needed many wire connections for each bed and room door light. They were also very difficult to install, and the site preparation was involved.
3. Previous devices were difficult to be interfaced with computers so as to perform full monitoring without human intervention [7].
4. Installation and site preparation costs were excessive, as the system needed scheduled maintenance [5].
5. Since previous devices were not interfaced with computers, no data could be stored to support the analysis of patient and nurse behaviors.
6. Elementary faults like wires cut from switches, light emitting diode malfunction, bulb failure, and human error were prevalent.

Our proposed system is intended to address all these weaknesses in a workable way to support high quality and reliability for life safety according to the international standards in the medical field [1,2,7].

1.2. Research Motivation

Ordinary nurse call systems are insufficient for customer satisfaction to provide safe and comfortable technology for patients, residents, and their families. A wired system requires up to 24 wires per room, thus generating spaghetti wiring, which in turn leads to increasing difficulties during installation, besides scheduled and unscheduled maintenance. Additionally, these traditional systems are incapable of storing data regarding both patient and nurse behaviors, resulting in human resource allocation with no data backup. Fitting a nurse call system can often be disruptive, time consuming, and expensive. However, this will no more become a problem with wireless nurse call systems [7,8,9].

2. Material and Methods

2.1. Hardware Material

The necessary hardware for our prototype consists of the following elements [5,6]:

1) Several power supply types to meet the DC voltage needs, as shown in Figure 3a for the Arduino Nano board and in Figure 3b for the Raspberry Pi2 Model B.
2) Arduino – Nano Board, as shown in Figure 4.
3) Wireless Transceiver serial UART (HC12), as shown in Figure 5.
4) Raspberry Pi 2 Model B, as shown in Figure 6.
5) Wiring and connectors for the Printing Circuit Boards, as shown in Figure 7.
6) Normal Push Button switches and toggles.
7) Variable switches, light emitting diode, resistors, and a buzzer (speaker) [10,11].
8) LCD Monitor screen.

Figure 3. a) Arduino DC Adaptor - b) Raspberry DC Adaptor

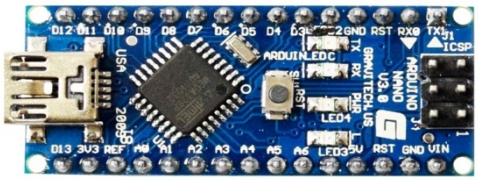

Figure 4. Arduino – Nano Board

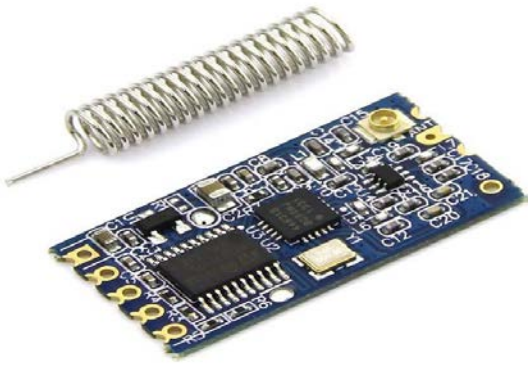

Figure 5. Wireless Transceiver serial UART (HC12)

Figure 6. Raspberry Pi 2 Model B

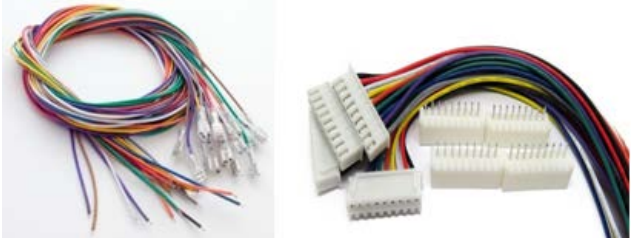

Figure 7. Wiring and connectors for the PCB`s

2.2. Software Material

Our software consists of the following elements:

1) QT Integrated development Environment (C++ program).
2) Atmel Studio Integrated development Environment [12,13].
3) Interface software between the computer & Arduino – Nano Board.
4) Dedicated computer program with WIFI compatibility.
5) Software simulators for our microprocessor and for using the laptop to develop and test the program code.

The software is split into 2 main modules

- Embedded software (Arduino Boards).
- Monitoring application (Raspberry Pi II Boards).

2.2.1. Embedded Software

This is the heart of the nurse call system. It is hosted on an Arduino board and is composed to two layers:

- Network layer: It is responsible for building and maintaining a self-healing mesh network between all nodes of the system.
- Application layer: It monitors the state of connected sensors and reports it to the monitoring application. In our nurse call system, this layer is configured to monitor and report the state of two push buttons, one indicating that the patient is calling a nurse, and the other one indicates that the nurse has responded to the call.

2.2.2. Monitoring Application

The monitoring application has five main functions

- Displaying the sensors' status.
- Triggering an alarm when a preconfigured sensor value is reached.
- Triggering an alarm if a node is disconnected from the network.
- Saving the sensor data into a database enabling data driven analysis of the monitored system.
- Sending email and/or SMS notification when a preconfigured sensor value is reached.

Part of our proposed program code for the Arduino is shown in Figure 8, and part of the code for the Raspberry Pi II Model B is shown in Figure 9.

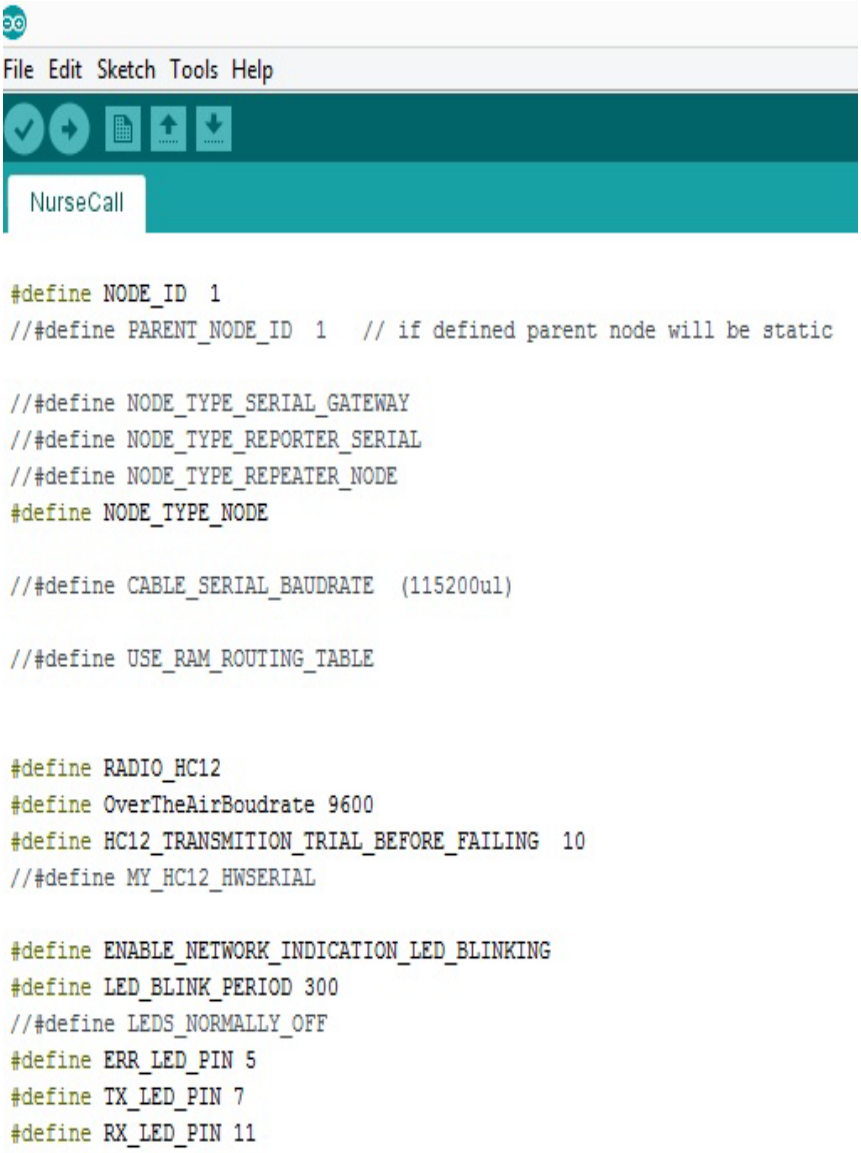

Figure 8. Part of the Arduino Program

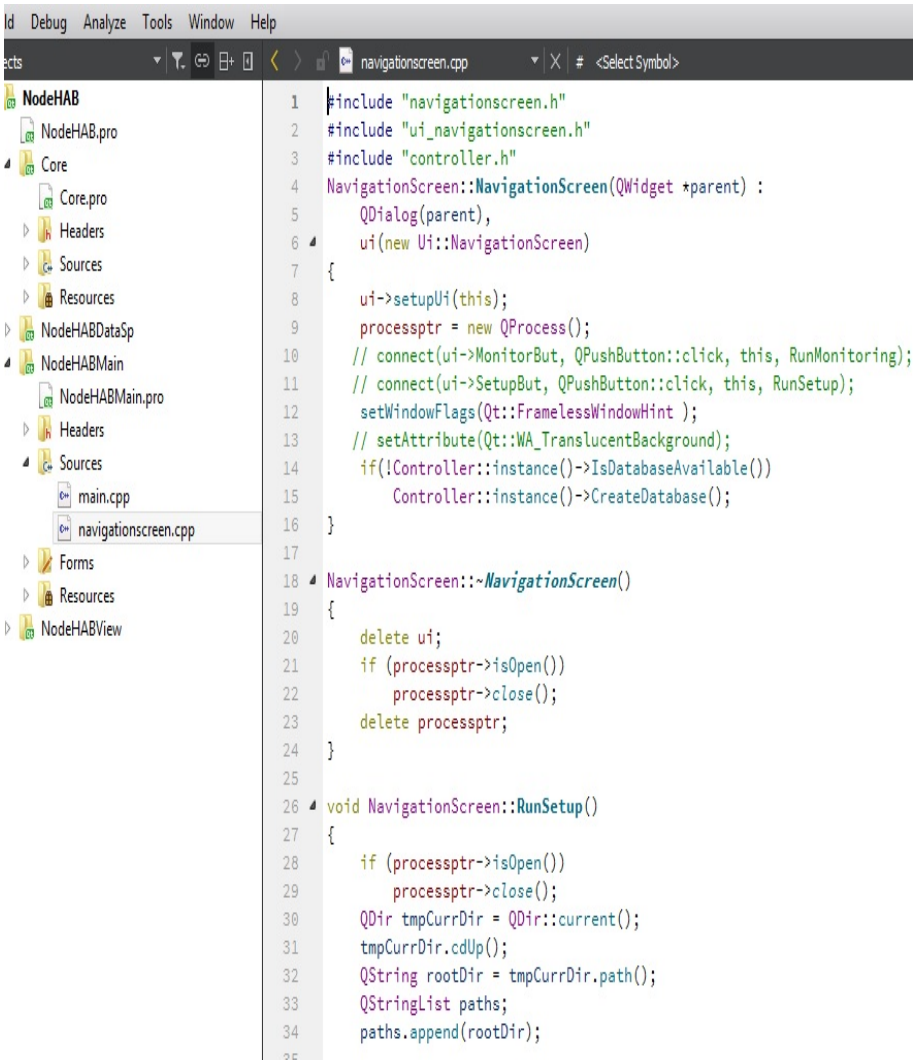

Figure 9. Part of the Raspberry Pi II Model B Code

2.3. System Description

2.3.1. System Block Diagram for Raspberry Pi II

This system is developed to run under windows or Linux in an embedded or desktop environment. It consists of four modules. Figure 10 shows the Four Main Modules of our system.

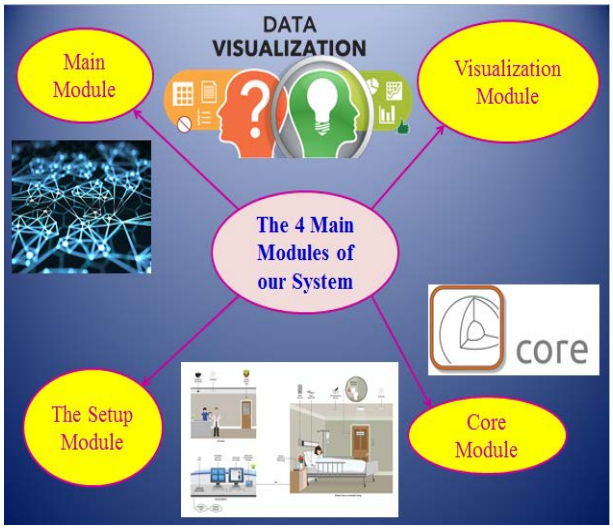

Figure 10. Main Modules of the system

1. The Core Module: It is responsible for collecting the data, signaling alarms, sending notifications (nurse alarm and remote alarms (sms messages / E-mails) and database interactions. For reliability this module runs on 4 different threads and is separated from the GUI thread.
2. The Setup Module: This is a GUI module responsible for collecting configuration data from the user and committing them to the database through the core module.
3. Visualization Module: This is a GUI module responsible for the presentation of the sensors data collected by the core module to the user.
4. The Main Module: This is a shell GUI module to enable selection between the setup and the view modules.

2.3.2. Main Features of the System

Our intended system provides several advantages as based on a self-healing mesh network to facilitate the removal and injection of nodes during run time. In case of node exclusion due to power shut-down, sudden-stop, or malfunction) its children nodes will automatically find another route to the base node. Other features (depicted in Figure 11) include:

1. Reliability

2. High quality
3. Maintenance free and Hassle free operation
4. Self-healing mesh network configuration
5. Wireless technology, so there is no need for any under construction wiring.
6. Accountability.
7. The possibility to set up the system to send e-mails to the decision makers in case a patient call is not responded to within a predefined time span (example: 3 mins), as shown in Figure 11 of system features.

Figure 11. Main Features of the system

3. Results

3.1. The Basic Achievements of Our System

Our system has been applied to five patient rooms in a hospital as shown in Figure 1, where we have successfully implemented our system and completely tested all its functions and features [7,9]. Each patient room had a wireless nurse call unit as shown in Figure 12. By pressing the button it triggers the signal alarm in the nurse station through the Gateway unit as shown in Figure 13 [4].

Real-time readings were securely uploaded to the Raspberry Pi boards which are accessible from the nurse desktop device or even from the technical desktop device as shown in Figure 15 a and Figure 15 b [14].

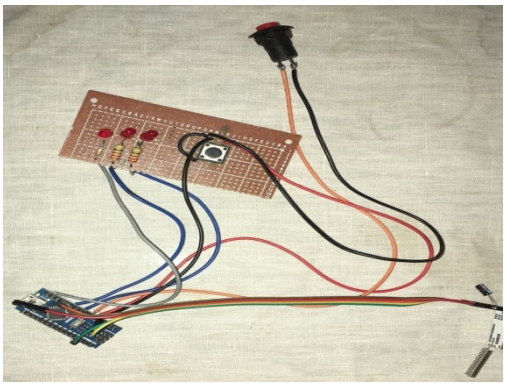

Figure 12. Nurse Call unit before Packaging

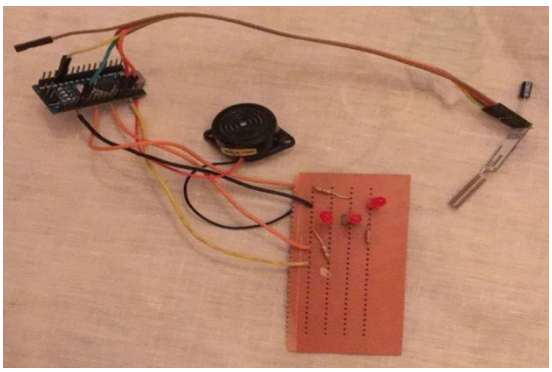

Figure 13. Gateway Unit before Packaging

Figure 14. Gateway Setup Screen

Figure 15a. Nurse Station Monitoring Screen at Normal Case

Figure 15b. Nurse Station Monitoring Screen at Alarm Case

Figure 15 a showing the normal case when No patient is demanding any help or medical assistant & Figure 15 b is showing that patient Room # 5 is asking for Nurse support. Our system is flexible & customized so it could be retuned according to the client demands.

Each node in the network presented itself to the controller at the initial login and then the controller responded with a login confirmation. The controller broadcast periodically a network discovery order. Each node responded with its current parent and the number of

hoops to the controller. The controller used this information to build the current network topology as shown in Figure 16.

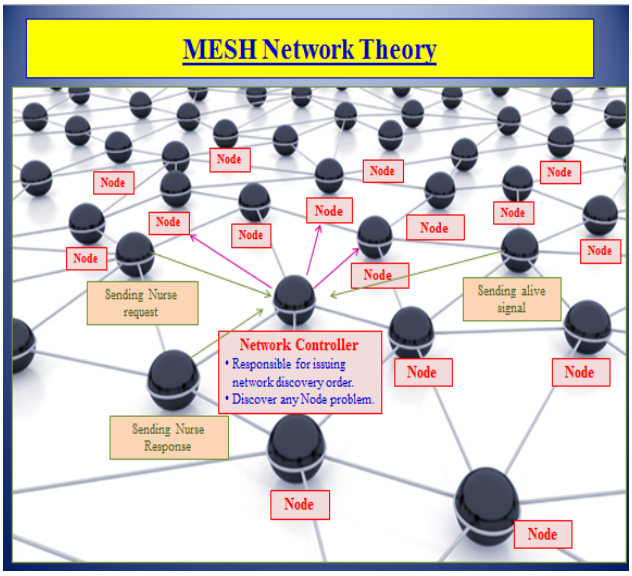

Figure 16. MESH Network Theory

In the end, our proposed system succeeded in displaying and monitoring our five patient room prototype (in the Complex Army Medical center in Kobry El-Koba). So, it is now ready to be installed in any clinical center as it can manage up to 254 patient rooms in any hospital or medical center with the flexibility given to the customer for any alteration or tuning in the data base or screening monitors or even for adding additional features.

4. Conclusions

Our intended system utilizes wireless technology because there is no need to install cables to any of the call points, and the impact is minimal as shown in Figure 1 explaining system configuration. Wireless systems also have lower installation and operating costs over a traditional hard-wired system, as well as being quicker and easier to install. Wireless configuration offers complete flexibility and mobility, which makes our system infinitely changeable and expandable, thus allowing for the constant ability to deal with ever changing priorities and demands [9,11]. Additionally, our system is safe [15], reliable and cost-effective. It can be designed to suit individual requirements and needs and adapted to work within any hospital budget. It also has a variety of features which can help to maximize staff efficiency and improve the overall quality of care offered to health care clients and patients.

Our intended system proved successful at performing its main function. It also featured a fast response time in case of a pressure fault problem. The result was indeed an amazing system without any human errors. Also the Research and Development (R&D) carried out for the gas monitoring system gives the opportunity to any developing team to build a complete control system, as well as to try to reach a high level of technology at the international market scale.

5. Future Work

In the near future we seek to produce more systems (at the mass production scale), in order to decrease all the human errors and to increase the safety levels in the healthcare buildings. Also since our system is computer-interfaced and modular, it can be easily upgraded to send sms and e-mails.

Research may also continue to develop more efficient and intelligent systems that will be able to take actions and make decisions according to prescribed scenarios [14,15,16].

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